# Development of Dynamic GEO-Line Software for Learning Geometry: A Usability Assessment

**Diego Avila-Pesantez**

Grupo de Investigación en Innovación Científica y Tecnológica (GIICYT), Escuela Superior Politécnica de Chimborazo (ESPOCH), Ecuador,

https://orcid.org/0000-0001-8394-5621

**John Silva**

Facultad de Informática y Electrónica, Escuela Superior Politécnica de Chimborazo (ESPOCH), Ecuador,

https://orcid.org/0000-0003-2445-0308

**L. Miriam Avila**

Facultad de Mecánica, Escuela Superior Politécnica de Chimborazo (ESPOCH), Ecuador,

https://orcid.org/0000-0001-9421-287X

**Alex Breedy Quintanilla**

Information Technology School, Oregon Institute of Technology, USA,

https://orcid.org/0000-0002-3569-3068

**Abstract**: Educational software reinforces the learning process in high school. This way, GEO-line software for learning geometry will strengthen teenagers' skillset between 15 and 16 years old while using this new application. The SCRUM and ADDE methodologies applied include the analysis, design, implementation, and evaluation phases as the core principles for software development. The technological toolset selected was the NEXTJS framework with server-side rendering technology. Strapi API CMS handled the content used on the model, view, controller (MVC) patterns, and REST architecture for communication and the PostgreSQL database. ISO/IEC 25010 metric was considered for the usability evaluation and applied with a pool of 80 students who were surveyed using the adapted USE and PSSUQ QUESTIONNAIRES with a Likert scale. The findings demonstrate that GEO-line software meets the satisfactory higher standards usability level by measuring pedagogical capacity, ease-of-use, and ease-of-learning parameters. This research turns the geometry learning reinforcement tool for students into a fun and operational way to increase the student's skillset.

**Keywords:** Educational software, GEO-line, geometry, usability

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## Introduction

The learning process of mathematics and related sciences is a core subject characterized by the learning complexity level and embedding difficulty, especially in Geometry and Measurement, due to covering concepts of representation and analyzing properties of the shapes and their relationships, which can be graphic and symbolic (Feudel & Dietz, 2019; Jiménez & Reyna, 2016). While learning geometry, three cognitive activities must be considered: a) construction related to the design of geometric elements; b) reasoning, which links discursive and argumentative processes; and c) visualization, focused on spatial representation (Diaz-Nunja et al., 2018). The traditional teaching methods used by instructors or faculties only reinforce the subject's memorization of knowledge in students. It generates mechanical learning without adequate analysis, reducing the abilities that geometry allows to develop, such as problem-solving, critical thinking, reasoning with logical argumentation, and spatial visualization (Herbst et al., 2017; Marmolejo-Avenia & Vega-Restrepo, 2012). In the case of Ecuador, the 2018 PISA evaluation tests established that 70% of the students did not reach the basic level required to understand mathematics and geometry, classifying it as a learning challenge with an unenjoyable study method and a high level of rejection in the school curriculum (Herbst et al., 2017). In this scenario, they use digital technologies as alternative tools that allow students to explore and consolidate the knowledge acquired, reinforcing the educational process and aptitudes that increase students' perception of Geometry. This way, incorporating these technologies provides the students with different pathways of understanding and reasoning, reinforcing mental structures that expand and reorganize their cognitive resources (Reyes, 2020).

The use of educational software in Geometry is limited due to teachers' lack of training or knowledge of how dynamic geometry programs can be applied in a classroom. These facts present a new way of learning approach through the modeling, visualization, manipulation, and construction of geometrical shapes such as objects, points, lines, and circles, which present a certain level of difficulty to do manually (Aydos, 2015). The most widely used geometry program is GeoGebra, which is very suitable as a learning medium that helps students to understand the relationship between mathematical models and their graphical representation. The program also allows the demonstration, visualization, and dynamic modification of geometry contents (Ziatdinov & Valles Jr, 2022). However, in van-Borkulo et al. (2021), some difficulties that students present when using GeoGebra are exposed, for example, lack of previous training using the program, specifically syntax rules, the layout design of the objects within the program environment, and problems executing commands. Therefore, the learning process could confuse inexperienced students and take time to become familiar with the commands and functions within the program (Saputra & Fahrizal, 2019).

In this environment, the purpose of developing educational software GEO-line is to create didactic materials for teaching Geometry based on the contents approved by the Ministry of Education of Ecuador, incorporating

formative feedback to enhance learning in high schools. With the implementation of the GEO-line tool, it will be possible to design and organize an outstanding teacher curriculum and syllabus with instructions, challenges, examples, technical notes, evaluations, and bibliographic information feedback through an interactive e-learning platform to reinforce the learning process. Also, this study was intended to analyze the usability of educational software using multiple choice questions designed on USE (Usefulness, Satisfaction, and Ease of Use) and PSSUQ (Post-Study System Usability Questionnaire) questionnaires (Lund, 2001; Rosa et al., 2015), based on the ISO 25000-SQuaRE standard.

## Related work

Kukey et al. (2019) studied previous teachers' experiences using educational software and digital materials in the classroom. The participating teachers used Lego MoretoMath to create didactic material based on students' needs. Thus, the study verified that using educational software minimizes the previously analyzed difficulties, and the students learn while interacting with the software, increasing reasoning skills for problem-solving. The high impact that dynamic geometry systems (DGS) have on mathematical skills is exposed in Juandi (2021) and Saputra and Fahrizal (2019). They used educational Geometry software for the elaboration of interactive material. The results show a significant improvement in the students' evaluations who reinforced their learning skills while using this software. Geometry learning methods applying games also present positive results, improving students' creative capacity through adventure activities, and motivating the student in the educational process (Navruz & Tasdemir, 2019; Zeng et al., 2021).

## Geo-line Software

The methodologies applied for the GEO-line development process were the Agile SCRUM and ADDE (Analysis, Design, Development, and Evaluation) methodologies that allow the software to adapt naturally to the functional and educational requirements of the users, working iteratively and incrementally (see Figure 1).

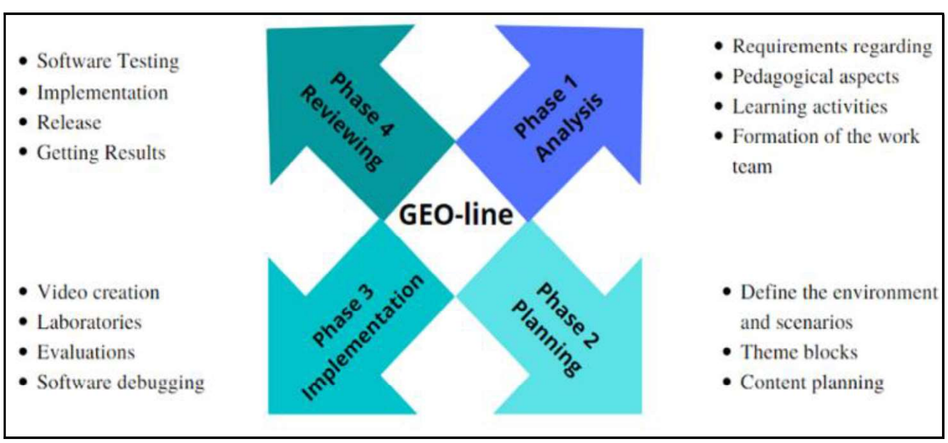


Figure 1. Simplified development phases of GEO-line based on SCRUM & ADDE (Avila-Pesantez et al., 2018)

### A. Analysis

The GEO-line software concept was defined as an educational genre that obtains practical and constructivist learning skills in young men. In this phase, a preliminary study was conducted by meeting teachers and students to collect the desired functionalities. Then, the technical and economic resources were considered while analyzing and verifying the feasibility of implementing this project. Finally, the risks that could arise during the development process were identified to avoid later inconveniences.

### B. Planning and estimation

As the next step, we established the functional user with access to the software and the T-Shirt estimation method. A schedule of activities was created with their respective subtasks, people involved in the project, and their roles. With all these elements defined, the product backlog was made, which contains all the requirements defined in the user stories and techniques for educational software. In the Sprint Backlog, the number of iterations for this project was detailed.

### C. Implementation

The architecture design of the GEO-line software was created based on the user's needs. The client is intended to use the NEXTJS framework with server-side rendering technology to ensure a fast user experience. As shown in Figure 1, the client-server approach allows students to use the application through a web browser, while the source of responses to student requests will be the server. Finally, Strapi API CMS was used on the server-side to implement the model, view, controller (MVC) patterns needed, the REST architecture for communication, and the PostgreSQL database (see Figure 2).

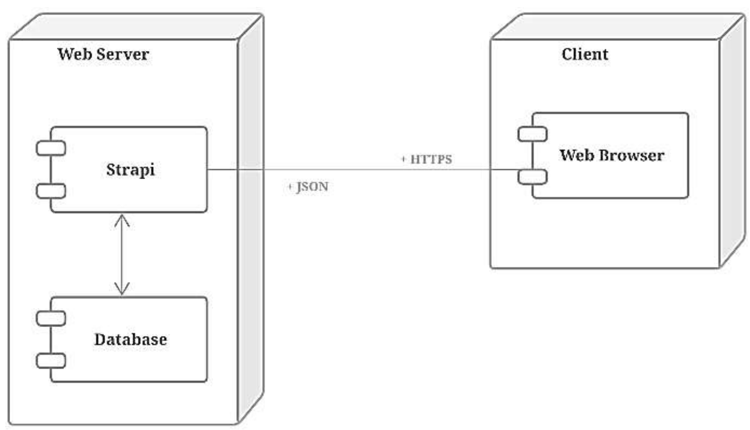


Figure 2. Educational software architecture

For the visual representation of the functionalities structure, Wireframes were used (see Figure 3), which guarantees compliance with the agreed purposes, focusing on the content’s organization, function layout,

navigation, and ease of use. After the designs were concluded, the educational software was encoded based on the product backlog, which had 24 user-stories and 5 technical-stories through 4 iterations of 2 weeks each one.

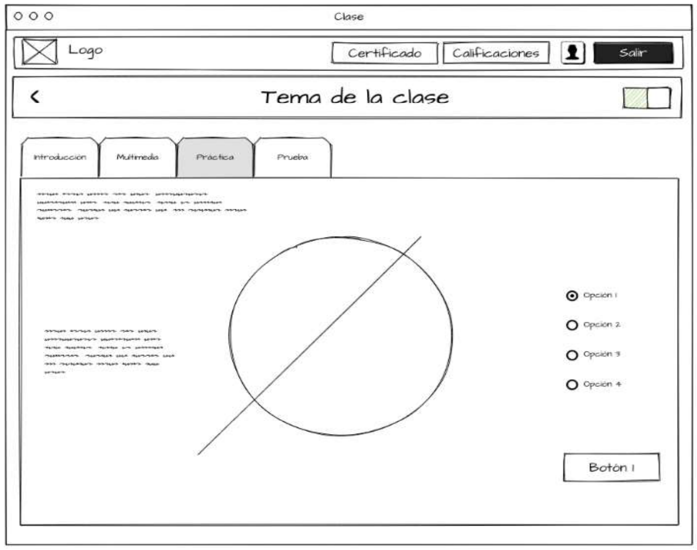


Figure 3. Class Screen Wireframe (Dynamic Geometry Educational)

### D. Reviewing and releasing

In the last stage, functional tests were performed with teachers and students to verify the content's organization and presentation. During the evaluation process, the students received an introduction to the educational software (see Figure 4). A topic was selected to start a class demonstration, which began with the theoretical foundatiions' review and a tutorial video (see Figure 5 and 6). With the theoretical bases established, the interaction of the geometric model continued (see Figure 7) and ended with a learning evaluation with multiple-choice questions (see Figure 8).

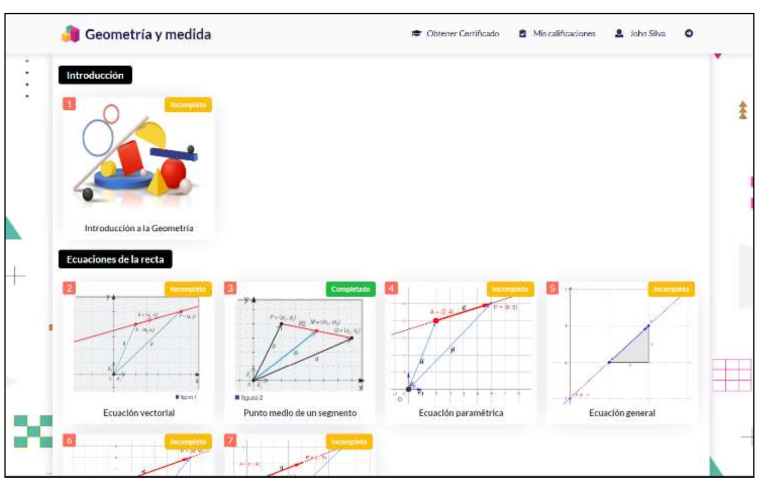


Figure 4. Screenshot of Homepage (List of classes)

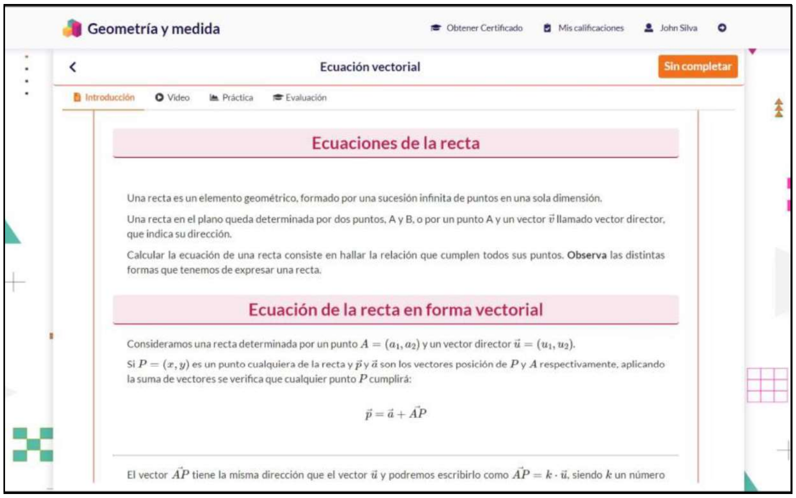


Figure 5. Theoretical foundations section

# Method

## Usability Assessment

An experiment was carried out to measure GEO-line's usability level (https://e-geometry-js.vercel.app/login), with the participation of 80 second-year high school students from 7 high schools in Riobamba – Ecuador, with a population sample between 15 and 16 years old (M=46 and F=34) with previous parents' permission granted to start up the experiment. Teenagers' participation was randomly established in each class for 6 weeks using online educational software, reviewing proposed Geometry content. In the seventh week, the Usability evaluation was carried out through 3 sub-characteristics (pedagogical ease, pedagogical ease, ease of use) based on the ISO 25000-SQuaRE standard.


Figure 6. Video tutorial on the topic

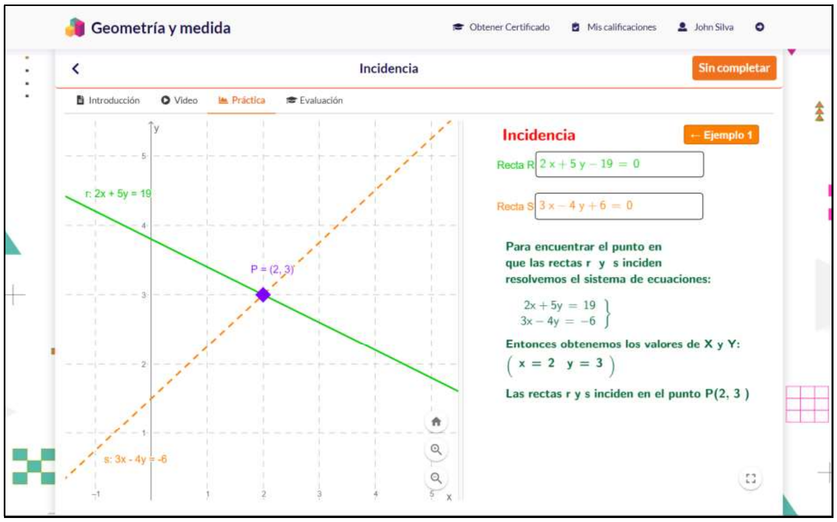


Figure 7. Interactive geometric model

For data collection, PSSUQ and USE questionnaires were adapted to determine the level of satisfaction concerning the educational software. A 5-point Likert qualitative scale was used for each question in the questionnaire (Strongly agree = 5, Agree = 4, Neither agree nor disagree = 3, Disagree = 2, Strongly disagree = 1).

## Results

Table 1 presents the results for the sub-characteristic of easy pedagogical understanding. It is observed that question 3 has the highest score, highlighting the feedback on the learning process implemented in the educational software.

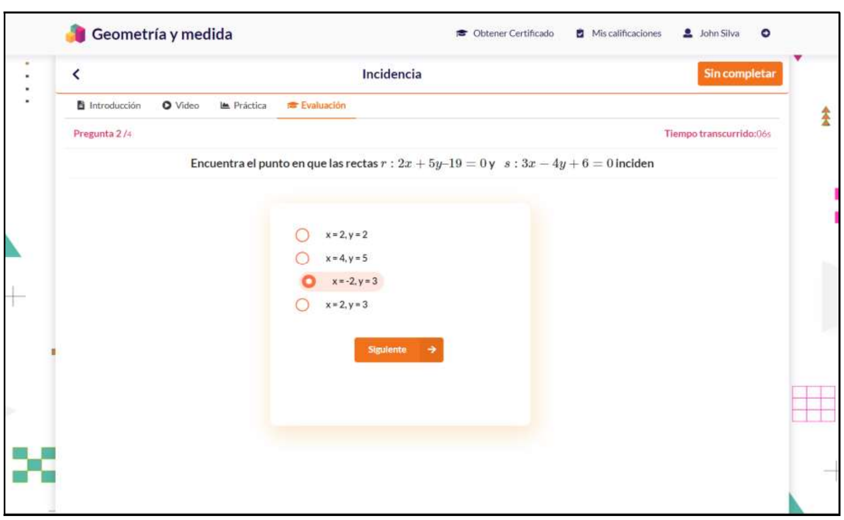


Figure 8. Learning assessment

About the sub-characteristic of ease of understanding or comprehensibility, it was established that interactivity, user interfaces, and a friendly environment allow students to reinforce their abilities to assimilate content through this new technological strategy (see Table 2).

Table 1. Pedagogical facility

| **Question** | **Average over 5** |
|---|---|
| The information in the introduction and the video for each class is clear and easy to understand. | 4.6 |
| The evaluation of each class has questions according to the subject matter, and I can answer them without any problem. | 4.3 |
| At the end of the evaluation, I can check my correct or wrong answers, and the procedure or way to solve each question is explained. | 4.7 |
| **Average** | **4.51** |

Table 2. Ease of comprehension or understanding

| **Question** | **Average over 5** |
|---|---|
| The display of the classes is pleasant. | 4.4 |
| I enjoyed interacting with the interactive figures. | 4.6 |
| I had complications in accessing my grades screen. | 4.3 |
| The information in the introduction and video of each class is clear and easy to understand. | 4.4 |
| I could go back to where I was before by **watching** the different screens. | 4.3 |
| I would recommend this educational software to a friend | 4.6 |
| **Global average** | 4.43 |

The results for the ease-of-use sub-characteristics are shown in Table 3. A general average of 4.45 is determined, highlighting the ease of interacting with the GEO-line. Percentage weightings were assigned for each evaluated subcategory to obtain the level of usability of the educational software (see Table 4), defined in the work of G. Quichimbo et al. (2021). Weights were then weighted to each subcategory, shown in Table 5.

Table 3. Ease of use or operability

| **Question** | **Average over 5** |
|---|---|
| I had no errors while using the educational software. | 4.4 |

| | |
|---|---|
| If I made a mistake, I could go back and continue navigating. | 4.2 |
| A message was displayed after completing a class or updating my profile. | 4.3 |
| A message explaining the error was displayed when entering the wrong e-mail address to log in. | 4.4 |
| It is convenient to navigate from the "Introduction" section of the class to the "Test" section. | 4.6 |
| It is easy to interact with all educational software. | 4.8 |
| **Global average** | **4.45** |

Table 4. Usability weighting

| Subcharacteristic | Average | Percentage achieved | Weighting |
|---|---|---|---|
| **Pedagogical facility** | 4.51 | 27.07% | 30% |
| **Ease of comprehension or understanding** | 4.43 | 35.44% | 40% |
| **Ease of use or operability** | 4.45 | 26.70% | 30% |
| **Total** | | **89.21%** | **100%** |

Table 5. Quality level indicators

| Measuring scale | Score | Satisfaction rate |
|---|---|---|
| **87.5%-100%** | Fulfills the requirements | Highly satisfactory |
| **50 % - 87.4 %** | Acceptable | Satisfactory |
| **27.5% - 49%** | Minimally acceptable | Unsatisfactory |
| **0-27,4%** | Unacceptable | |

With these results, it is determined that the GEO-line educational software obtains a usability percentage of 89.21%, corresponding to a Highly Satisfactory level (see Figure 9).

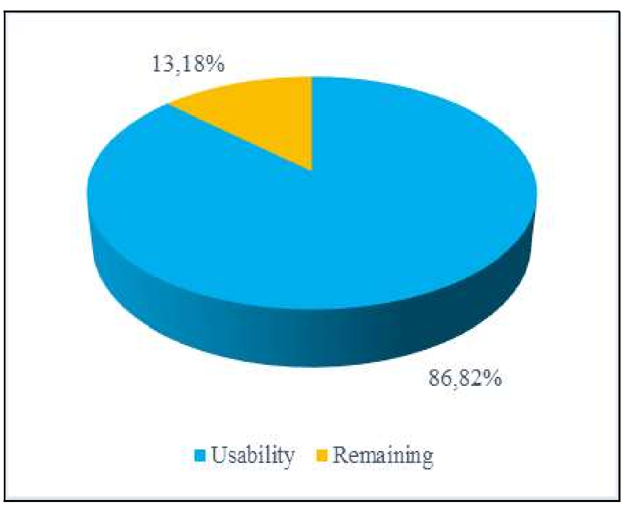


Figure 9. Usability level achieved

## Conclusions

This study aimed to develop educational software that reinforces the learning of geometry and measures the level of usability for first-year high school students in the city of Riobamba. The project management was accomplished with the SCRUM methodology complemented with ADDE, which effectively allowed the users' requirements. The selected architecture was client-server, using NextJS technologies for the visual part and Strapi API CMS for content management in a straightforward and easy-to-understand way. Creating interactive geometric objects was done with GeoGebra components, which were imported into the corresponding curriculum. In the experimentation, through a descriptive analysis using the data collected from the questionnaire, a highly satisfactory level of usability of the educational software was determined using parameters such as pedagogical ease, ease of understanding, and ease of use. It demonstrates the academic reinforcement that GEO-line offers in the learning process of Geometry at the high school level.

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